ISOCHRONOUS VARIABLE ENERGY CYCLOTRON OF

IPEN-CNEN/SP - INSTALLATION, USES AND PERSPECTIVES

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ABSTRACT

The cyclotron CV-28 installed at the Radiation Damage Division of IPEN-CNEN/SP, is a multi-particle radiation source where protons, deuterons, He^3 ions and alfa particles can be accelerated with variable energy up to 24, 14, 36 and 28 MeV respectively. The cyclotron is a verstile machine that can be applied in research and development of: radioisotope production - materials science - nuclear physics - activation analysis and others. First internal beam with 24 MeV protons has been obtained in April 23, 1981. First irradiation of Cu sample, at the external beam (beam current 1,5 uA), with 28 MeV alfa particles was performed in December 29, 1983. Main characteristics of the cyclotron are given together with a description of peripheral systems and experimental capability. Presently the accelerator is being optimized for continuous running.

INTRODUCTION AND FACILITY DESCRIPTION.

The cyclotron CV-28 ordered at The Cyclotron Corp. in 1975, was installed in its especially designed building in 1980. The installation of the peripheral equipment, consisting of: a) cooling system, b) electrical and electronic systems, c) vacuum system and beam lines, d) shielding, was started at that date and proceeded until December 1983, when the cyclotron became operational. The CV-28 model is a compact multi-purpose irradiation source and is presently utilized in major research institutions and hospitals, thus enabling the use and development new characterization methods for nuclear materials, as well as, powerful diagnostic methods in nuclear medicine, trace elements analysis and nuclear physics research. It has a total capacity for the installation of seven external beam lines, plus one internal target. Actually two external target stations are operational. Additional beam lines can be installed accordingly to research and development demand. The IPEN 91 cm cyclotron produces high quality external beams as shown in Table 1, which contains the manufacturer's nominal data.

TABLE 1

PARTICLE	EN.RANGE(MeV)	EXTERNAL CURRENT(uA)		INT.CURRENT(uA)
		$E_{min.}$	$E_{max.}$	
Protons	2 - 24	40	60	200
Deuterons	4 - 14	50	100	300
Helium-3	6 - 36	5	50	135
Helium-4	8 - 28	6	40	90

Tolerance: ± 0.5 MeV at $E_{min.}$, and ± 1.0 MeV at $E_{max.}$

Energy Resolution: 0.5% or 50 KeV - whichever is greater.

Further specifications of interest are: pole tip diameter of the main magnet 96.50 cm; average magnetic field 1.74 T (17.4 KG); weight of the cyclotron 22.8 tons. The geometry of main components is shown at the median plane cross section, in Fig.1. The ions are generated in a P.I.G. type source and are accelerated by two 90-degree Dees. The ion source consists of ion-heated cathods which eliminates the necessity of filaments and respective power supply. The Dees are connected through vacuum insulators to an inductor assembly located in the Radio-Frequency (RF) system. The RF operationg frequencies are selected by varying the inductor to the correct impedance and lenght. The magnetic field of the model CV-28 is shaped by three hill sectors with four sets of profile coils, to provide adequate field profile for isochronous acceleration of the ions. The pole tips of main magnet form the upper and lower covers of the vacuum chamber; this construction permits the upper half of the cyclotron to be raised for access to the acceleration region for maintenance.

The ion beam may be intercepted, at any radius, by the beam probe located inside de vacuum chamber. During extraction, the beam is deflected by an electrostatic channel (deflector) positioned between the Dees, passing afterwards through a focussing magnetic channel, before leaving the cyclotron at the exit port, (Fig.1). Two sets of three harmonic coils are located radially inside the acceleration region to provide for the centering of the beam in the cyclotron.

The support equipment is composed of: Anode Power Supply(PS)(6 A, 0-12 KV DC); Magnet PS (0-230 A DC); and Deflector, Dee bias, Ion source, Profile and Harmonic coils power supplies; plus hydraulic, pneumatic, cooling (air conditioning and water) and demineralized water systems. The layout of the cyclotron building is outlined in Fig.2, and contains 18 rooms for laboratories, staff, peripheral equipment and the control room. Additionally there are heavily shielded areas, comprising the cyclotron room and three experimental areas.

Presently, two target stations T1 and T2 are operational. The target station T1 is assigned to radioisotope production and T2 is a general purpose station used in radiation damage research. A general view of the cyclotron system is given in Figs.3, 4 and 5.

USES AND PERSPECTIVES.

Accordingly to the proceedings of the 8th.International Conference on Cyclotrons and their Applications of 1978[1] there were 109 cyclotrons in the world, 85 (78%) of which entered operation after 1960, and 51 (46%) after 1970. These figures show the growing interest in the use of this type of cyclic accelerator in diverse research fields. A statistical comparison of the applications of cyclotrons in world scale can be visualized on Table II.

TABLE II - Cyclotron Applications

PURPOSE	PURPOSE DISTRIB.(%)	BEAM-TIME DISTRIB.(%)
Isotope Production	100	23.1
Basic Nuclear Physics	98	39.0
Development	98	8.6
Bio-medical Applications	83	17.7
Solid State Phys.+Mat.Science	54	5.1
Other Applications	15	5.4
Activation Analysis	2	1.2

The sum of the above mentioned purpose distribution is obviously greater than 100%, due to the fact that the majority of cyclotrons are used in a multi-purpose mode. The interesting point is that 98% of the cyclotrons are being improved and developed in their experimental capabilities, which demonstrates the interest of the users in updating their machines, as well as, the adaptability of these accelerators to new working conditions. The statistical time distribution shows that the cyclotrons are mainly used for basic physical research (Nuclear and Solid State Physics, and Radiation Damage) (44.1%), and isot. production with bio-medical applications (40.8%).

The time distribution established for IPEN cyclotron is 70% of beam-time for Radioisotope Production and 30% for Radiation Damage Studies. Presently Zinc is being irradiated with 24 MeV protons, 15 uA currents for Ga^{67} production. Chemical separation methods are being improved simultaneously with the search of better sample holders to optimize production. Once established the methodology for Ga^{67}, then will be considered the production of Tl-201. I-123, Fe-52, Kr-81, Xe-127 and Ru-97. Short-lived isotopes such as C-11, N-13, O-15 can also be produced in the cyclotron and will be considered in the future. On the other hand alfa particle implantations are being performed in stainless steel of type 316 to simulate de (n,α) reaction in reactors, which produces He bubbles and swelling as a destructive consequence. Mechanical properties changes are measured by means of creep experiments at high temperatures (500 to 700ºC), and contolled atmosphere with the aim of reproducing the severe working conditions of power reactors[2,3,4]. Another advantage of cyclotron use in radiation damage study is that some hours of alfa particle implantation can simulate many years of fast neutron irradiation in a reactor[5]. These experiments are complemented by microhardness, electrical resistivity, magnetic after effect and optical and electron transmission microscopy. An in situ creep test device is in construction, planned to evaluate the mechanical property changes during cyclotron irradiation, and permit a better understanding of structure transformations at enhanced diffusion conditions[6,7]. Besides the constant parameter optimization, some technical improvements are programmed, one of them being a beam-scanning device to guarantee a homogeneous sample irradiation.

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BIBLIOGRAPHY

1.- J.A. Martin - CYCLOTRONS 1978 - 8th. Intern.Conf. on Cyclotrons and Their Applications - IEEE Tran.Nucl. Sci. NS-26, nº2 (1979).

2.- J. Hemmerich - R. Hölzle W. Kogler - The Jülich Compact Cyclotron - a Multi-Purpose Irradiation Facility. - Kerntechnik, nº2 (1977)

3.- M.P.Otero, G.Lucki - Electrical Resistivity Measurements of Nb-2.5 wt.%Zr Alloy in He atmosphere Before and During Fast Neutron Irradiation. - VII Iter-American Conf. on Mat. Techn. Oct.(1981)-Mexico City.

4.- G.Lucki, V.L.Galli - Effect of Neutron Irradiation, Temperature and Nb Additions on the Microhardness of Nuclear Materials.- VII Inter-American Conf. on Mat.Techn. Oct.(1981) Mexico City.

5.- H.Ullmaier - The Simulation of Neutron Induced Mechanical Property Changes by Light Ion Bombardment. Trans.Inst.Met., 34, 324, (1981).

6.- V.Sciani, P.Jung. - Diffusion of Helium in FCC Metals. Rad. Eff., 78, 87 (1983).

7.- V.Sciani, P.Jung, G. Lucki - Alfa Particle Implantation and He Diffusion Mechanisms in Au, Ag and Al. VI National Meeting on Condensed Matter Physics - Brasilian Soc. of Physics May (1983) São Lourenço - Brasil

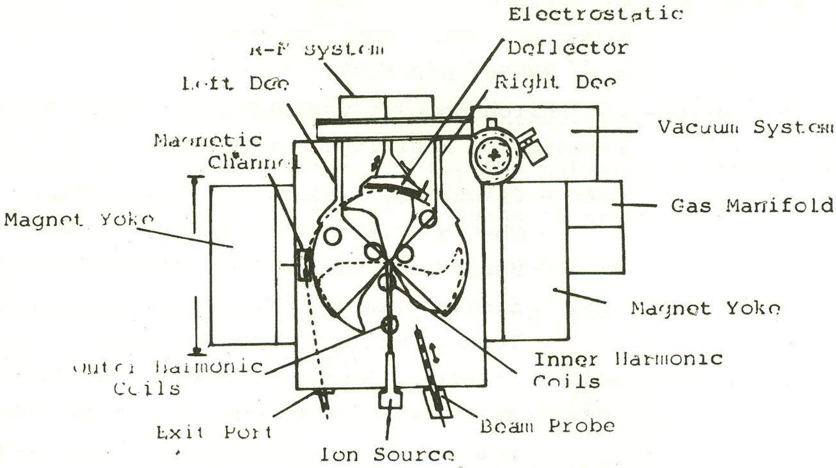

Fig.1 - Median plane cross section of the cyclotron CV-28.

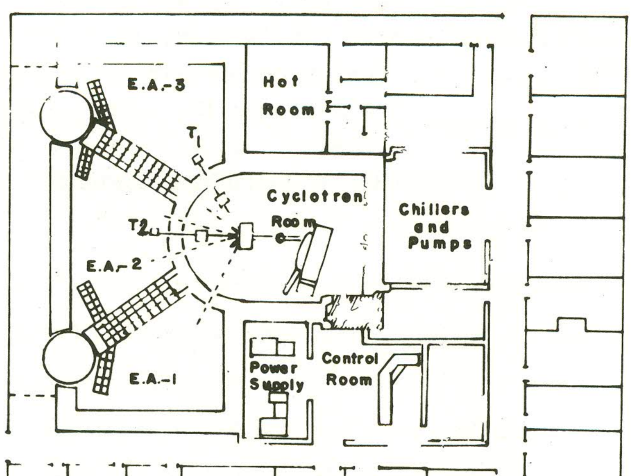

Fig.2 - Facility layout.

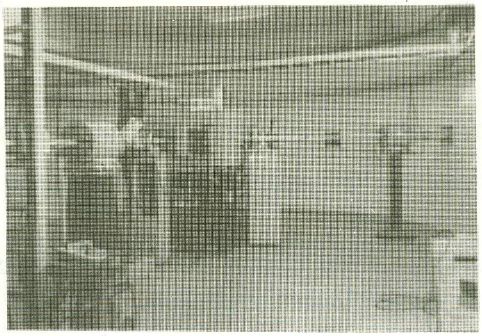

Fig.3 - Switching magnet with main beam line (left) and beam line nº1 (right).

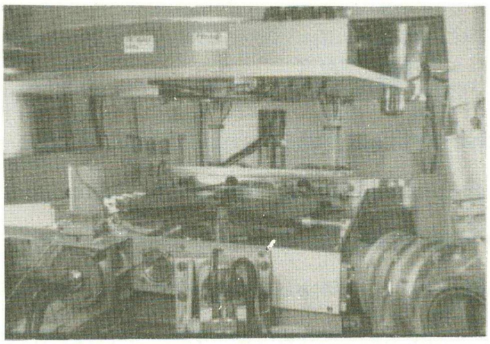

Fig.4 - Open cyclotron, showing the acceleratio region the Dees and the magnetic sectors(hills).

Fig.5 - Control Panel.